A SURFACE STUDY OF A DEPRESSION-TYPE PRESSURE WAVE

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ABSTRACT

A study is made of the surface micro-features of a depression-type pressure wave that passed across the Cloud Physics network in southwestern Ohio, April 7, 1948. Pressure change, wind, rain, temperature, and humidity observations in the network are described with the aid of isochrone charts and micro-synoptic charts at 5-minute intervals. Comparison of the micro-charts with a section of the conventional surface weather map suggests a possible linkage between the depression-type wave and a squall line or pressure jump line.

INTRODUCTION

During the past several years considerable interest has been shown in atmospheric pressure waves, especially those in which an abrupt rise in pressure occurs. Tepper's pressure jump theory [1, 2] is an outstanding example. Many investigators have also noted an opposite type wave in which there is an abrupt fall in pressure. Brunk [3, 4] calls it a "pressure pulsation," and suggests that in extreme cases it may develop into a tornado. Tepper [2, 5] calls it a "depression-type wave" that is propagated along an inversion surface, and has reported a case in which a cloud bank was desiccated upon passage of the wave. Williams [6] has observed that depression-type waves frequently follow the passage of elevation-type waves or pressure jumps.

Depression-type waves are a meteorological oddity In spite of the intense pressure falls associated with them' they do not generally coincide with severe weather or even "bad" weather. For this reason there appears to be little justification for even noticing them. On the other hand, it is interesting to note just what weather conditions may occur with an intense depression-type wave. This paper is a descriptive presentation of the surface micro-features of one such wave.

The case of April 7, 1948, is presented, using data from the 1948 Cloud Physics Project, Wilmington, Ohio. The Project network, which has been described elsewhere [7], provided graphic records of pressure, temperature, relative humidity, rainfall, wind direction, and wind speed at 55 surface stations distributed over a small area (8 miles by 20 miles).

MICRO-SYNOPTIC FEATURES

PRESSURE

The changes in pressure were striking. The reproduction of 12-hour barograms in figure 1 shows the pattern of pressure change at each station. Even over this small area there was considerable variation in the pressure change pattern.

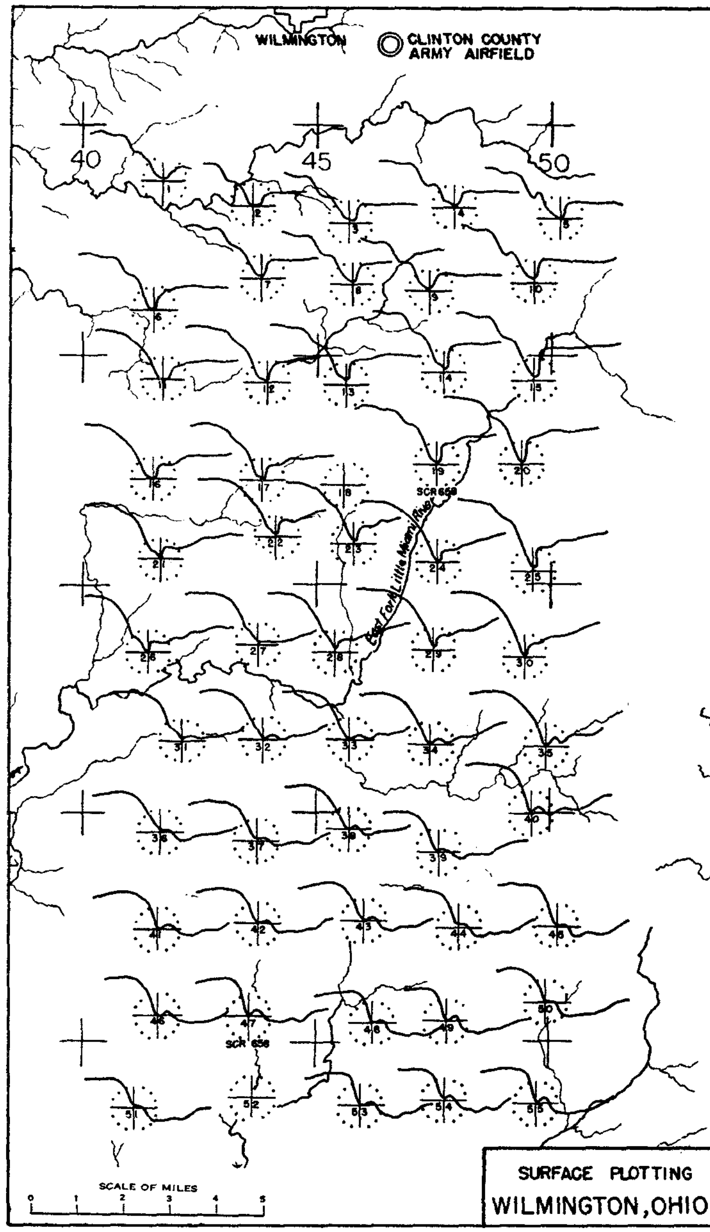

FIGURE 1.—Reproduction of 12-hour barograms, showing the pattern of the depression wave at each station in the Cloud Physics network, April 7, 1948.

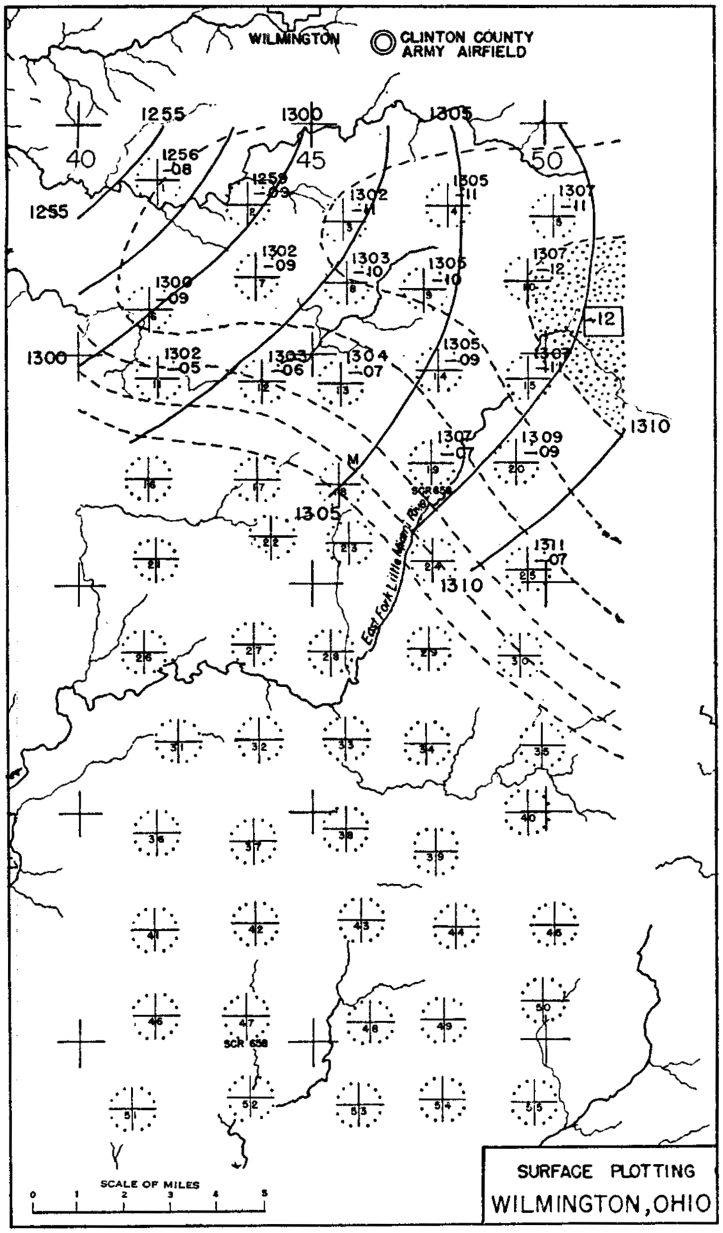

Figure 2.—Isochrone chart (EST) of the first trough line, April 7, 1948. Isochrones are for 2.5-minute intervals. Dashed isopleths show the depth of the trough line for 0.02-inch intervals.

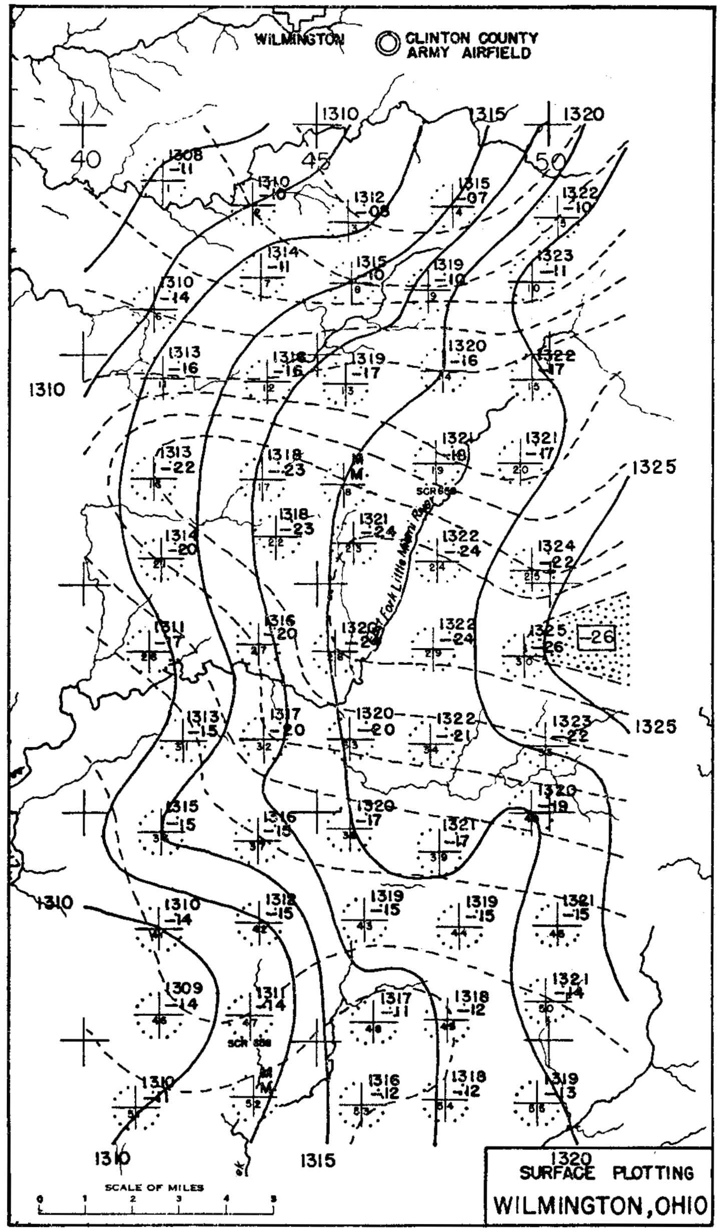

Figure 3.—Isochrone chart (EST) of the second trough line, April 7, 1948.

It is apparent that this pressure wave was not a simple one. Some of the traces show small rises or leveling off between periods of fall. Actually there were at least three distinct trough lines involved. Figures 2, 3, and 4 are isochrone charts showing the movement of these trough lines. A rather shallow trough, traversing only the northern portion of the network, occurred first. It was followed by a much deeper trough, which traversed the entire network. The third trough was very shallow and traversed only the central and southern portions of the network.

Depths of the first and second troughs increased as they moved eastward. Depth of the first was 0.12 inch by the time it passed off the network at Station 10. Depth of the second was 0.26 inch when it passed off the network at Station 30. The third trough had a maximum depth of 0.06 inch along the southern tier of stations. It is possible that greater depths may have been attained beyond the network.

The first trough line was fairly uniform in curvature. The second and third were very irregular. In fact, the curvature of the second was so irregular in the vicinity of Stations 36–45 that its continuity is in doubt. There may have been two trough lines, not quite joined together, in this vicinity.

Average movement of trough lines was from west to east, and speeds along paths of maximum depth averaged from 46 to 48 mph. There was considerable variation from average values; e. g., the speed of the second trough apparently reached 90 m. p. h. for a 2.5-minute period in the vicinities of Stations 18, 19, and 20.

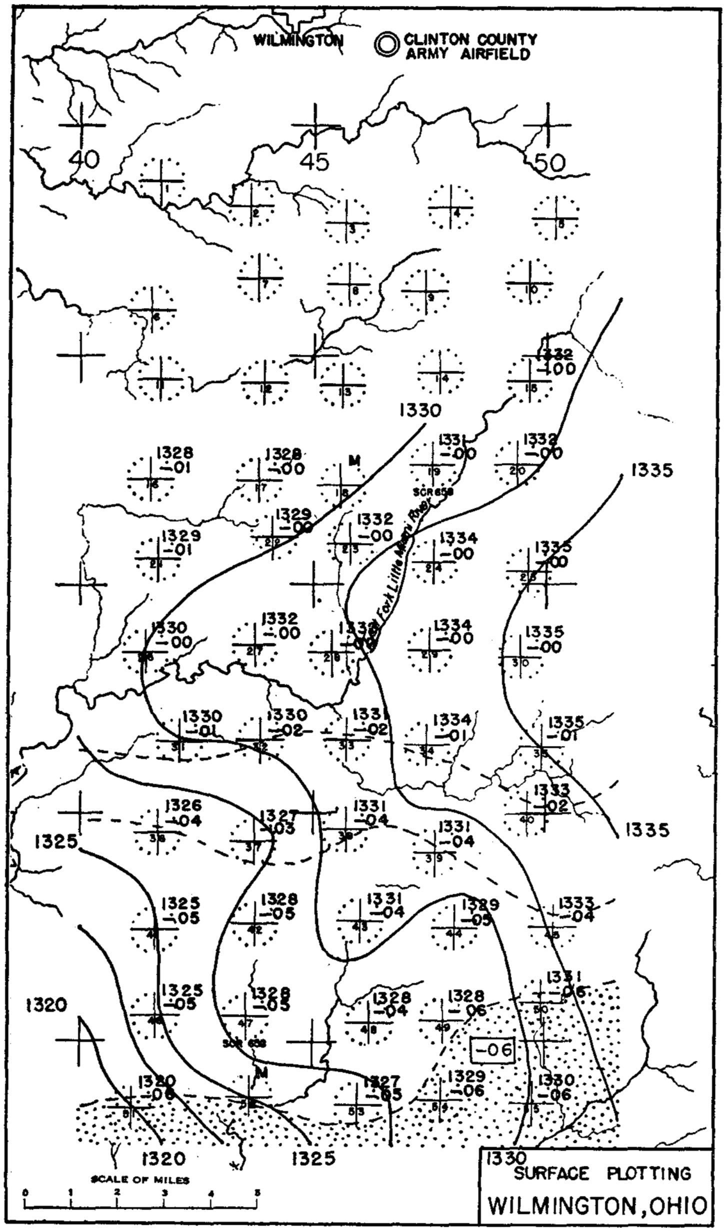

FIGURE 4.—Isochrone chart (EST) of the third trough line, April 7, 1948.

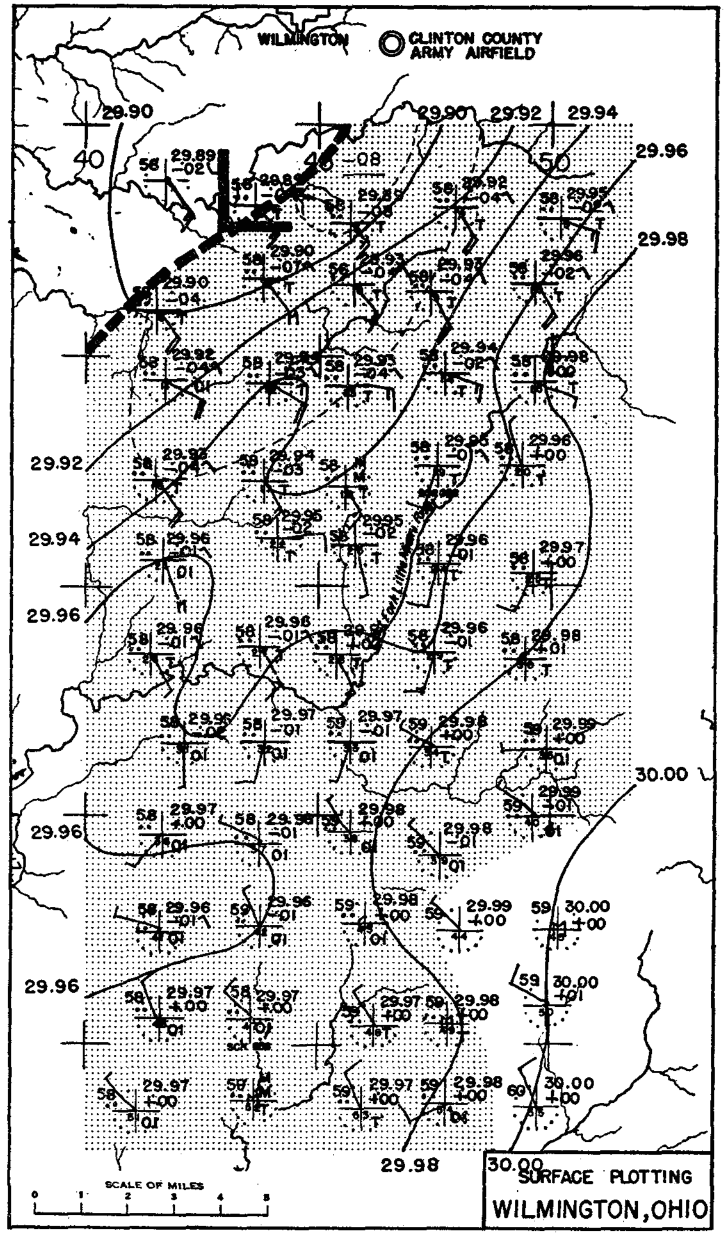

FIGURE 5.—Micro-synoptic chart for 1300 EST, April 7, 1948. Data are plotted as follows: Sea level pressure in inches of Hg; pressure tendency in hundreths of inches per 5 minutes; rainfall in hundreths of inches per 5 minutes; temperature, present weather, and wind in the conventional manner. Chart is analyzed as follows: Trough line as a heavy dashed line; isobars for each 0.02 inch; isallobars for each 0.04 inch per 5 minutes. Areas of precipitation are stippled.

Pressure changes are most graphically shown in the 5-minute micro-synoptic charts in figures 5–11. Rates of fall as great as 0.13 inch per 5 minutes (Station 20, fig. 9) occurred, and gradients as great as 0.08 inch per mile (vicinity of Station 11, fig 7.) occurred. These values are comparable to those observed in squall lines investigated from similar data [7] and are 50 to 100 times greater than normally observed in intense macro-systems.

Stations in the northern portion of the network showed abrupt pressure rises following the passage of the second trough line. Except for the abrupt falls preceding them, these rises resembled pressure jumps. However, they were lacking in other features, such as gusty, shifting winds, thunderstorms, and temperature breaks that often accompany pressure jumps.

A closed low center on the wave was fortunately located such that it passed directly over the network. The center is best shown in figures 8 and 9.

WIND

Winds were very light northwesterly prior to the approach of the wave. As pressure began to fall, winds shifted to southeasterly. As the first trough line passed and the second approached, the shift was to east-southeast and east. Following the passage of the second trough line winds did not shift again until pressure began to rise; then there were weak shifts to northeast and north. The passage of the third trough line did not appreciably alter the direction of the winds in the southern

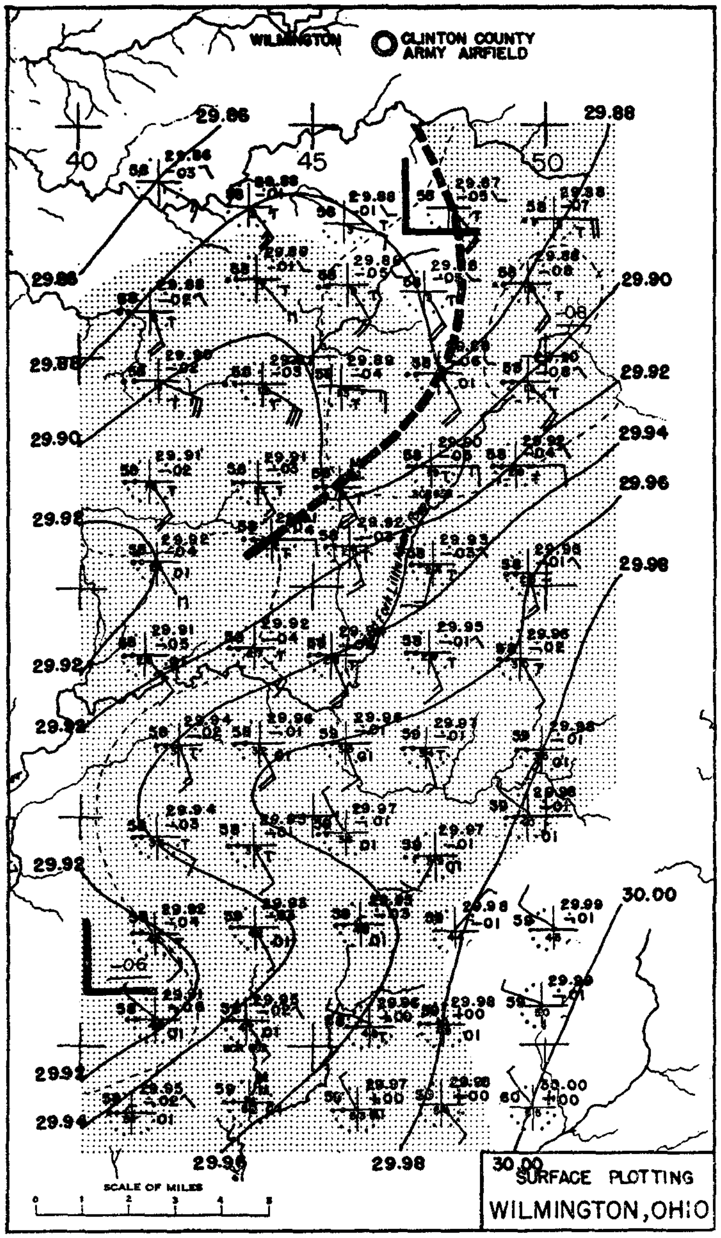

Figure 6.—Micro-synoptic chart for 1305 EST, April 7, 1948. The first trough line has moved to the north central portion of the network.

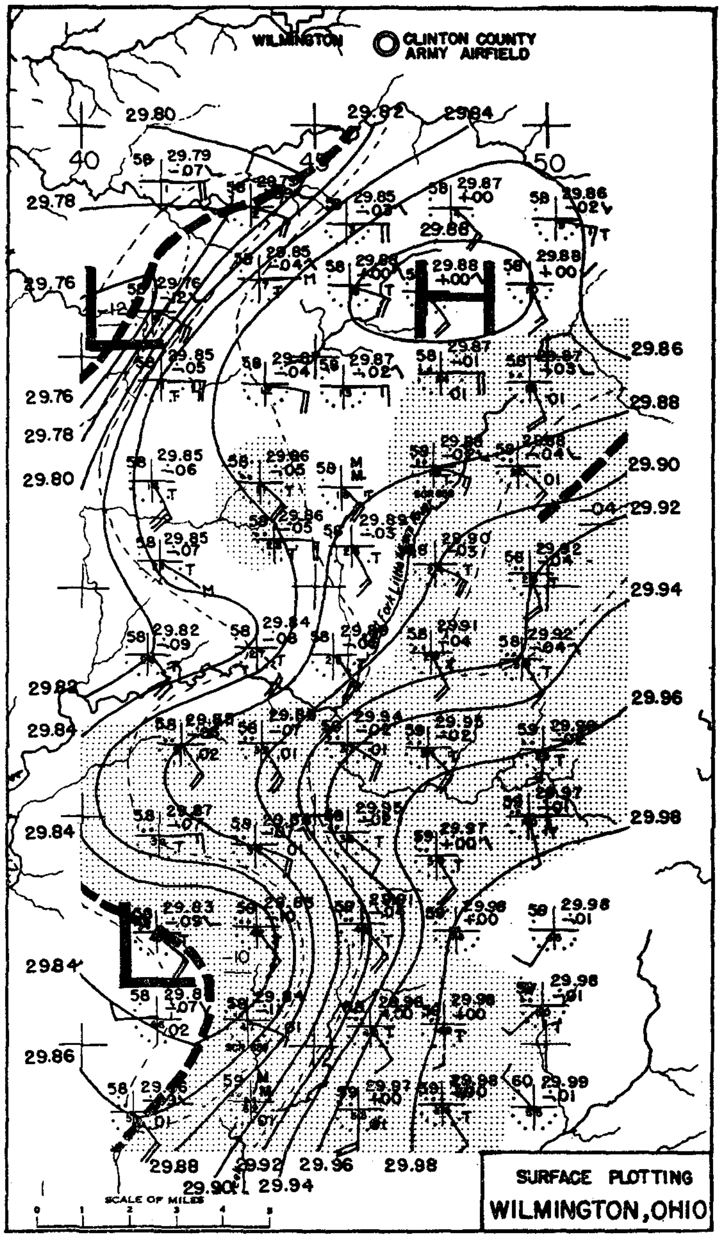

Figure 7.—Micro-synoptic chart for 1310 EST, April 7, 1948. The first trough line has passed off the network and the second trough line is entering the network at the northwest and southwest.

portion of the network; they remained generally from the southeast.

Wind speed prior to the approach of the wave was very light—less than 5 m. p. h. As pressure began to fall, wind speed increased. Maximum speeds from 21 to 38 m. p. h. were reached 5 to 10 minutes later. In some instances speeds remained high for several minutes; in others speeds diminished steadily following the maximum. Double maxima were recorded at some stations because of the approach of two separate trough lines. In general, speeds increased as trough lines approached and decreased after their passage. Speeds were generally greatest in areas of maximum pressure gradient, but destructive speeds were never attained. Wind speeds in excess of 30 m. p. h. were attained at 13 stations. The maximum speed of 38 m. p. h. was recorded at Station 24.

Winds did not conform to the pressure fields in the manner of macro-systems. They tended to blow at right angles to the isobars toward lower pressure, perhaps in response to isallobaric gradients. As the pressure troughs moved, there was an appreciable lag in the shifting of the winds to their pre-trough directions.

Although winds increased as pressure gradients increased, the speeds of 21 to 38 m. p. h. were exceedingly small in relation to the gradients. A regression of wind speed on depth of the trough yielded an average speed of 1.32 m. p. h. for each 0.01 inch depth with a range from 1.10 to 1.76 m. p. h. Brunk [3] has made a similar regression for another case. *His results give the wind* speed in miles per hour equal to one-half the numerical value of the total pressure fall expressed in tenths of millibars. This formula applied to the April 7, 1948,

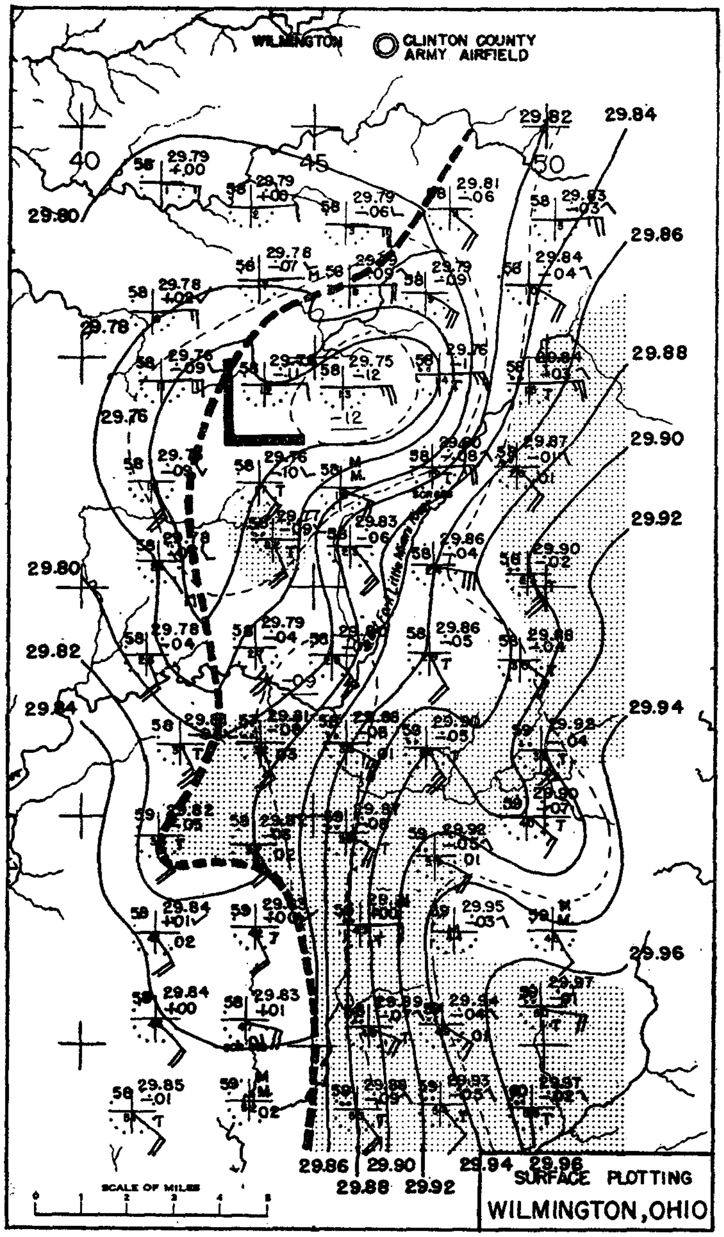

FIGURE 8.—Micro-synoptic chart for 1315 EST, April 7, 1948. The second trough line is now over the network.

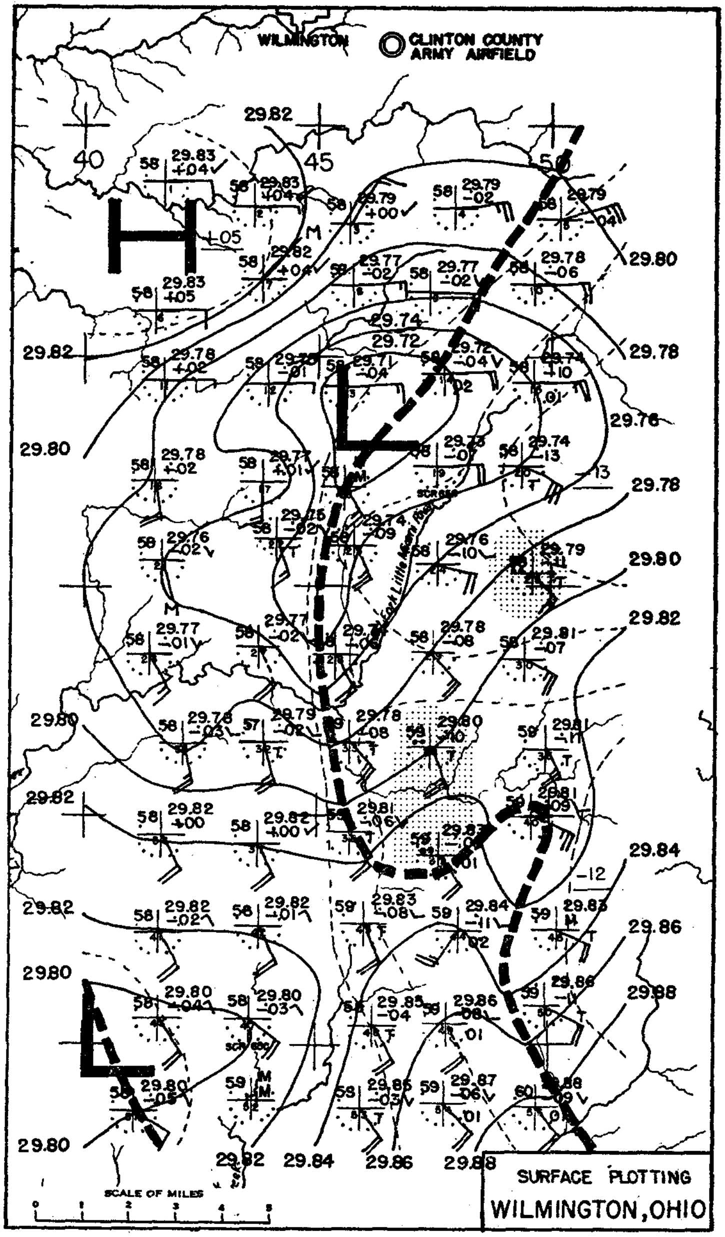

FIGURE 9.—Micro-synoptic chart for 1320 EST, April 7, 1948. The second trough line has moved eastward, while the third trough line is just entering the network at the southwest. A micro-High is beginning to build at the northwest.

case gives an average wind speed of 1.70 m. p. h. for each 0.01 inch depth of the trough. The value is a little high and suggests that perhaps an empirical formula should include the rate of pressure fall, as well as the amount of fall.

RAINFALL

Rain fell over virtually all of the network prior to the passage of the wave and had begun 1 to 2 hours prior to its approach. It may be inferred from the sectional synoptic chart, figure 12, that this rain was due to thunderstorm activity. The amount of rainfall was light; the greatest amount measured at any one station was 0.09 inch. Most significant is the fact that rain ceased as the depression wave passed. Rain ceased in the northern tier of stations upon passage of the first trough line, and had diminished over the northern third of the network before passage of the second trough line. Rain in the remaining areas ceased upon passage of the second trough line. By the time the third trough line passed no rain at all was falling.

TEMPERATURE AND HUMIDITY

The passage of the wave had virtually no effect upon temperature. Temperature prior to the wave passage ranged from 57° F. to 61° F. and changes during wave passage did not exceed 1°.

Humidities were high at the approach of the wave, ranging from 90 to 100 percent. The high humidities may be ascribed to the fact that rain had been falling. Although there was a slight fall in humidity as the trough lines passed, it was usually less than 5 percent, and was probably due to the cessation of rain.

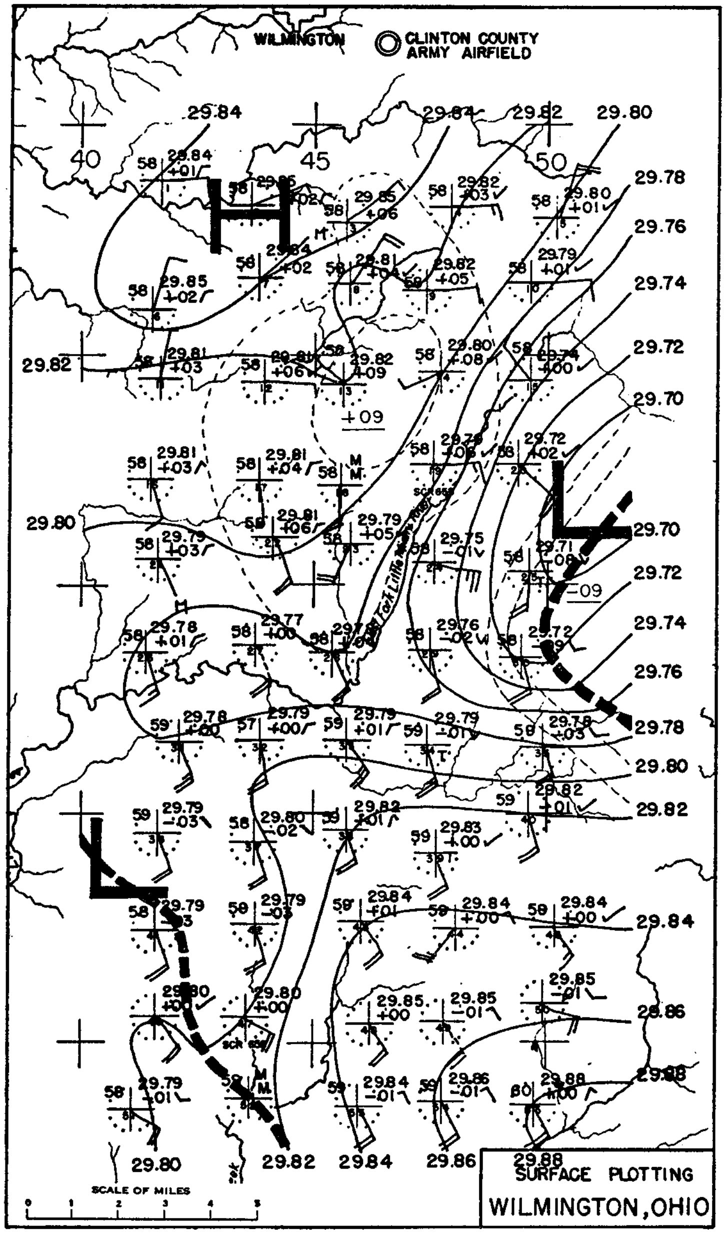

FIGURE 10.—Micro-synoptic chart for 1325 EST, April 7, 1948. The second trough line is almost entirely east of the network, while the third trough line is advancing slowly from the southwest.

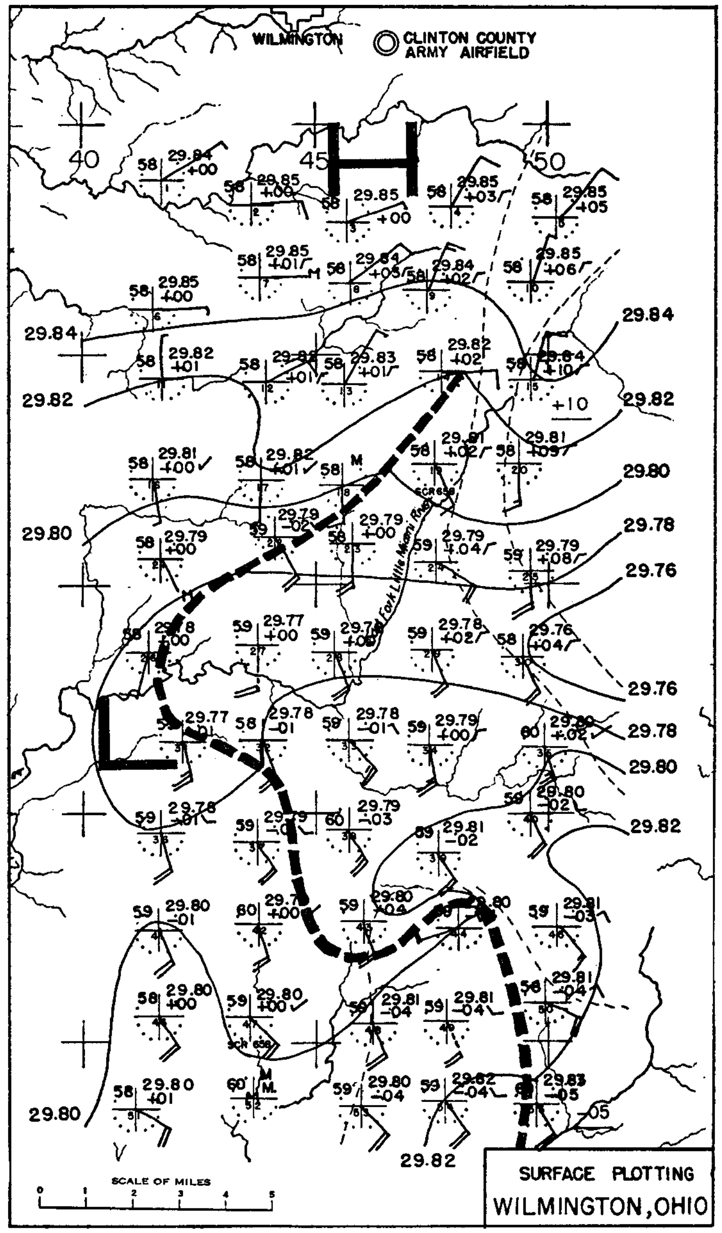

FIGURE 11.—Micro-synoptic chart for 1330 EST, April 7, 1948. The third trough line is now centered over the network.

SYNOPTIC RELATIONSHIPS

The sectional synoptic chart for 1330 EST, April 7, 1948 (fig. 12), is approximately synchronous with the passage of the wave over the network. Although the wave had attained a depth of 29.71 inches (1006 mb.) at the time of the map, its existence is not apparent. Pressures at nearby Cincinnati and Columbus were 1011.2 and 1013.2 mb., respectively.

The depression wave may have been related to the squall line shown on the sectional chart. The 6-hourly reports of thunderstorms and rainfall indicate that the squall line was most intense along a line approximately from Terre Haute, Ind., to Pikeville, Ky. The pressure field surrounding the squall line indicates that it coincided with a pressure jump line, so we may infer that a pressure jump line coincided with its earlier positions, also. If we assumed that the maximum amplitude of the jump coincided with the maximum amount of rainfall, its position would have been in the vicinity of Terre Haute, possibly somewhat east and south of it. We are certain that the squall line was weak in the vicinity of the network, since no appreciable jump was recorded, and since only a small amount of rain fell.

From the above reasoning we conclude that in addition to the depression wave there was also a pressure jump. We also conclude that they did not achieve their maximum intensities at the same time, nor were their centers of maximum amplitude coincident with each other.

The author [6] has observed frequent combinations of pressure jumps and depression waves in which centers of maximum amplitude were offset from each other. In

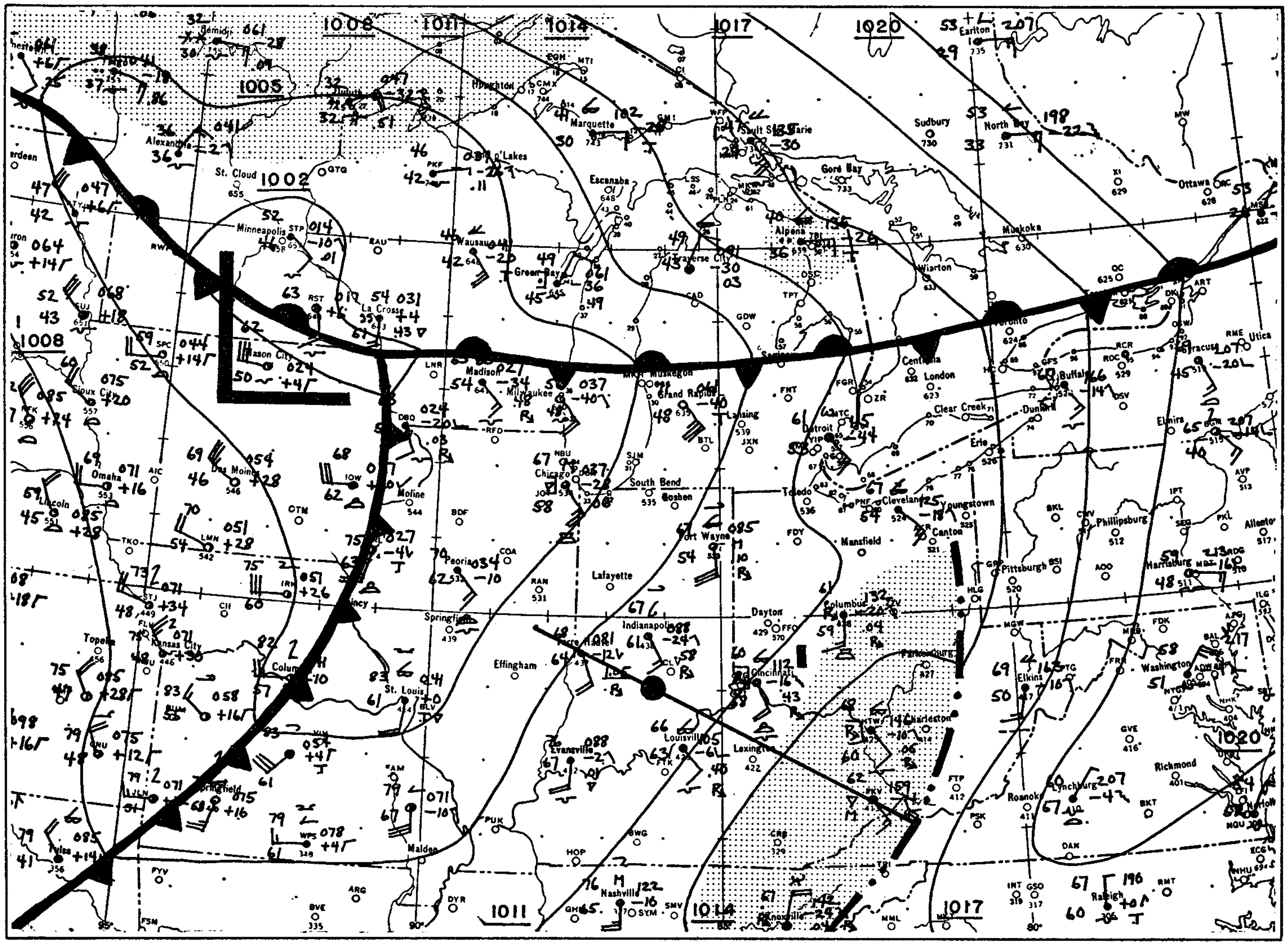

FIGURE 12.—Sectional synoptic chart for 1330 EST, April 7, 1948. A line has been drawn indicating the inferred line of maximum intensity of the squall line. The solid circle indicates the inferred center of maximum amplitude of the pressure jump. Location of the network is shown as a solid rectangle in southwestern Ohio.

some cases small, intense fields were completely offset from each other, so that some stations observed only the pressure jump, while others observed only the depression wave. The case presented is apparently in this category.

CONCLUSION

The depression-type wave appears to be of minor importance so far as its immediate effect upon weather is concerned; but its overall importance may be vastly greater in its relationship to the pressure jump line. This relationship, the multiplicity of trough lines in the wave, the offset effect, and the possible role in the genesis of tornadoes leaves an interesting field for more detailed investigation.

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